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REPORT NO. N00014-80-C-0188

MARINE PERFORMANCE MONITORING (MPM) SYSTEM

FOR FF 1052 CLASS SHIPS

INSTALLATION OF THE MPM SYSTEM ON USS JESSE L. BROWN

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14 JULY 1982

FINAL TASK REPORT

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MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
CONTRACT NO. N00014-80-C-0188

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SECTION I SUMMARY

1. Since this report covers the activities comprising the task of Contract No. N00014-80-C-0188, Contractor's conclusions and recommendations contained herein are preliminary and are subject to review and possible revision after David W. Taylor Naval Ship R & D center (NSRDC) has completed the evaluation program which extends beyond the date of this report.

2. Under the cognizance of NSRDC, a Marine Performance Monitoring System was installed on the USS JESSE L. BROWN, FF-1089, as part of a broad program to determine means by which ships' energy (fuel) consumption can be reduced.

3. The MPM System is based upon the same general procedures and same basic computer programming as used by a performance monitoring system that had been previously applied to merchant ships.

4. Input data is collected manually from local-reading instruments. Existing instruments were used where possible and supplementary

4. (continued)

instruments were installed as necessary to provide adequate data for computing plant heat balances, overall specific fuel rates, and component efficiencies. Input data is manually entered into a desktop type computer and output is produced on paper tapes which are mounted on output forms. Output is also displayed on a Performance Analysis Board which makes the data available for operating personnel and facilitates the analysis of the data.

5. It was demonstrated that the system can provide information which will enable the operating personnel to effect reductions in fuel consumption. It was also shown that the procedures for operating the system are well within the capabilities of the ship's engineering officers. However, there are indications that personnel turnover, infrequent ship operation at steady-steaming conditions, and lack of time available due to high levels of priority workload may cause the system to fall into disuse. Accordingly, it is projected that some shore-side agency will have to sustain the effective use of the MPM System.

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SECTION II - INTRODUCTION

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
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SECTION II INTRODUCTION

1. The energy "crunch" which has developed over recent years has brought a sharp focus on the urgency for reducing the fuel consumption of ships. The Shipboard Energy Conservation Research & Development Office at the DAVID W. TAYLOR NAVAL SHIP R & D CENTER, (DWTNSRDC), at Annapolis, has been conducting investigations to develop means by which fuel consumption of naval ships can be reduced. At the early stage of these investigations, extensive machinery performance optimization trials were conducted on two ships of the FF 1052 Class. These trials showed that the operating data outputs were not adequate for the ship engineers to determine either overall plant efficiency or component efficiencies. Further, it was not possible to measure the effect of change in a component's performance and to assess the effect on the entire system.
The standard engineering procedure for determining overall power plant efficiency is the heat balance calculation. This calculation and the associated flow diagram also

1. (continued)

provides the data for determining component efficiencies for auxiliary machinery, such as feed pumps, turbogenerators, condensers, and forced draft blowers. The calculations are very lengthy to perform by manual calculations and on most ships the original instrumentation is not sufficient to provide the input data that is used in the heat ballance calculation. Recent advances in computers and instrumentation have led to the development of equipment which can provide a relatively simple system for processing data and obtaining solutions to the heat balance equations. With such a system installed on a ship, the engineers have the capability of quickly determining the performance parameters. Then adjustments can be made to plant operating conditions to progressively determine optimum performance. Additionally, over an extended period of time, data history will be collected and stored and eventually that information can be used to project degradation of performance of key components. In order to investigate whether or not improved ship power plant operating efficiency and improved fuel conservation

1. (continued)

can be obtained by applying performance monitoring systems, DTNSRDC and two selected engineering contractors have carried out programs to develop two alternate MPM systems that are especially designed for the FF 1052 Class ships. The FF 1052 Class were chosen for the following reasons:

A. It is the largest single class of steam-powered combatant ships.

B. It is the class with the largest total annual fuel consumption.

C. It has a relatively simple engineering plant configuration of two boilers, one main turbine, and one propeller.

D. It uses a 1200 psig steam pressure for the plant and, accordingly, can be scaled up to twin and quad shaft plants.

E. The application of MPM Systems to FF 1052 Class could readily be extrapolated to other steam-powered ships of the Navy.

2. This report concerns one of the aforementioned MPM systems and for purposes of identification, this system will be referred to as the "BROWN MPM SYSTEM",

2. (continued)

since the initial installation was made on the USS JESSE L. BROWN, FF 1089.

Principal features of the Brown MPM System are as follows:

A. The operating procedures, calculation methods, and computer programming follow the general precepts of a ship propulsion plant monitoring system called PREDIKT 10-STEAM which was jointly developed by the SHIP RESEARCH INSTITUTE OF NORWAY and A/S MARITEK, a marine engineering and naval architecture firm in Norway. PREDIKT 10 systems have been installed on more than 40 merchant ships.

B. Certain additional instrumentation was installed to provide input data that is adequate for heat balance calculations. Included in this additional instrumentation are the horsepower/thrust meter, flowmeters, pressure gauges, thermocouples, stack gas oxygen meters, and RPM indicators.

C. Each of the instruments or indicators which provide data for the MPM System is marked with a special blue nameplate which describes the item being measured and contains the identification number corresponding to the number of the Input Data

C. (continued)

Recording Form.

D. Input data is collected manually and recorded on the Input Data Recording Forms, which are organized to facilitate the data collection by having one form for the fireroom and a second form that covers the engine room and auxiliary machinery rooms.

E. The input data is processed by entering it into the Hewlett Packard 9815S computer. The computer then performs the following:

Scans input data to confirm that values are within reasonable range, or identifies any items that are out of range so that engineer can recheck the value.

Heat Balance and component performance calculations.

Provides a paper tape printout of output data as listed on the Output Data Form and includes overall plant fuel rate.

Provides a paper tape printout of the values of pressure, temperature, enthalpy, and flowrate at key points of the heat balance/flow diagram.

Provides a paper tape printout of the plot of data trends for key parameters.

F. The tapes of Input Data, Output Data, and Heat Balance can be posted on the Performance Analysis Board where personnel

F. (continued)

can compare the results of a set of data to the corresponding Base data or to other data sets taken previously. Data sets can also be filed in the Input/Output Data File which is a loose leaf notebook.

G. The HP 9815S computer uses magnetic cassette type tapes, which contain the data processing programs, the heat balance and component performance calculations, hull fouling calculations, and storage for key data that has been collected. The calculations are specifically applicable to the FF 1052 Class and the program can be used for any shaft horsepower load that the ship is operating.

3. The MPM System is designed with the purpose of providing sufficient information for the operating engineers to "tune" the plant so that optimum efficiency can be attained. The fuel consumed, the specific fuel rates (lb. fuel per SHP-hour), and the steam flow rates can be compared for different modes of plant operating and by doing so the optimum conditions for fuel conservation can be identified. In the same way machinery components can be analyzed and items

3. (continued)

with lower efficiencies (and higher steam flow rates), can be investigated so as to determine whether or not improper settings of controls, worn parts, and/or off-optimum operation may be causing higher fuel consumption. The MPM System is installed as an operational tool to give the operating engineer better information upon which he can make decisions and at the same time to increase his knowledge of how the plant operates. Fuel conservation has a double impact on a naval vessel since it reduces a major element of operating cost and it increases the capability of the ship by extending the operating range.

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SECTION III - PROJECT OBJECTIVES

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SECTION III PROJECT OBJECTIVES

1. Design/Select a manual entry MPM System for the FF 1052 Class ships which will promote fuel conservation by providing the machinery operating personnel with indicators of;

   A. Plant overall specific fuel rate, in units of Lb fuel per Shaft Horsepower-hour

   B. Efficiencies of principal components

   C. Plant heat balance date

   D. Trend Diagrams for key parameters

   E. Hull fouling.

2. Based upon in-service information and performance results, evaluate the concept feasibility of the System with regard to;

   A. Mechanical considerations,
      e.g., maintaining instruments.

   B. Personnel considerations
      e.g., training of new personnel

3. Utilize the data and observations gathered during the installation, testing, personnel training, and in-service operation of the MPM System to develop recommendations for;

   A. Corrections/modifications to the MPM System to improve the effectiveness of the system.

   B. Modifications to the power plant to achieve improvements in fuel economy.

C. Alternate operating procedures to achieve improvements in fuel economy.

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SECTION IV - REVIEW OF PROJECT ACTIVITIES

SECTION IV REVIEW OF PROJECT ACTIVITIES

1. The interrelationships and sequence of performing the project activities are shown by Fig. IV - 1.

2. To make a preliminary determination of the Input Datapoints, which are defined as the instrument readings and propulsion plant conditions that are recorded and then manually fed into the computer, the following materials were reviewed and studies:

   ship piping diagrams,

   machinery manufacturers' performance and physical characteristics data, and

   test data from certain Energy Conservation Sea Trials conducted by DTNSRDC on USS HAROLD E. HOLT, FF 1074.

   A preliminary selection of the Program output was also prepared. This included component performance parameters, heat balance data, and trend diagrams.

3. The next step in the project was to make an in port visit to the designated test ship for the purpose of:

   surveying the existing instruments,

   briefing the ship personnel on the operation and objectives of the MPM System, and

MPM PROJECT-WORK FLOW DIAGRAM

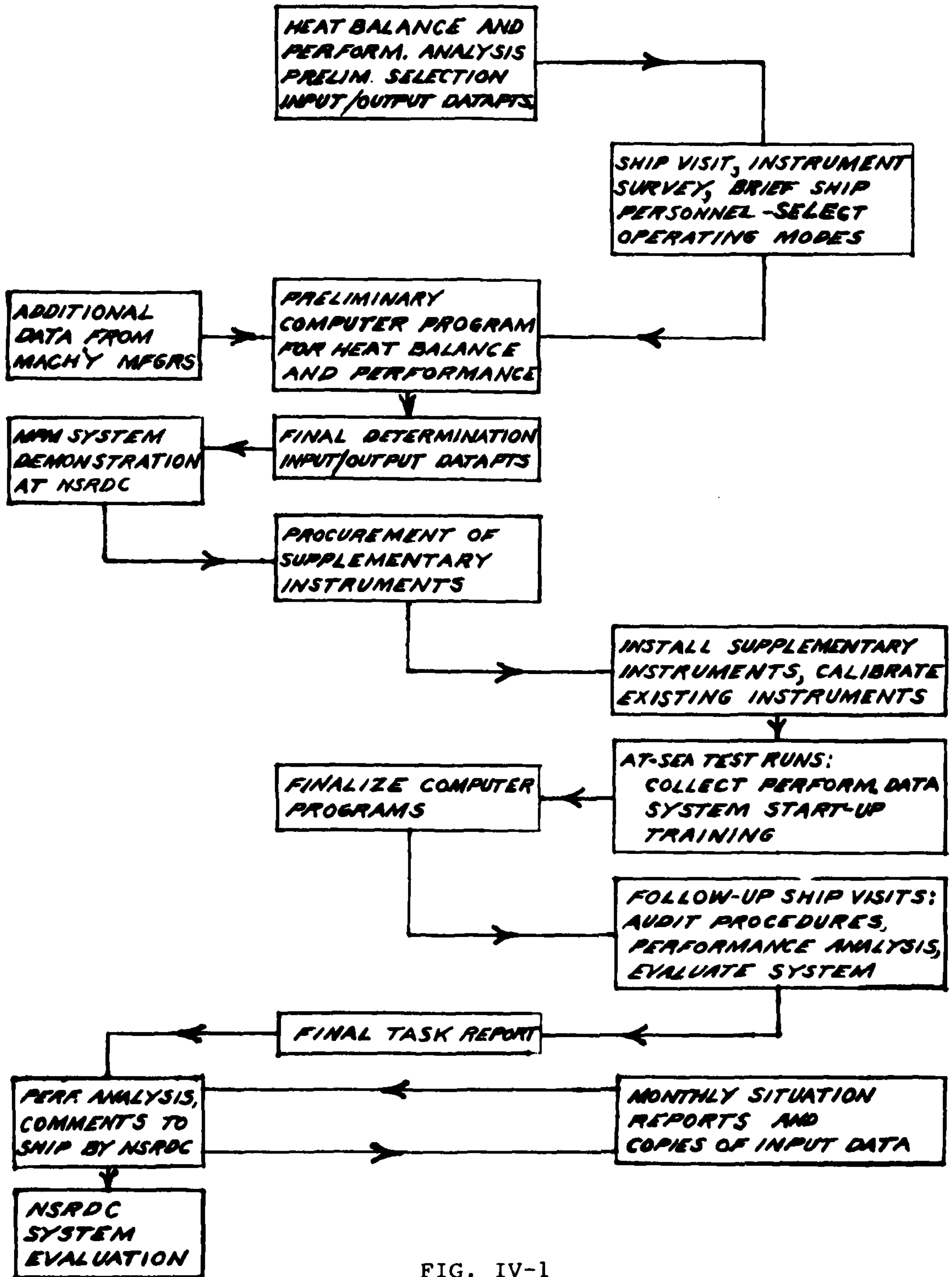

FIG. IV-1

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3. (continued)

obtaining the recommendations and inputs from ship personnel with regard to the selection of the Base Conditions, which are the horsepower levels and the associated modes of operation that are most frequently used when the ship is at sea. Ship engineers also reviewed the preliminary Input Datapoints and program Output Data and made suggestions which would make the monitoring more effective

The initial contract work schedule was idealized in that it assumed that the test ship would be available whenever MPM activities were to be performed. Considerable time was required by the various Navy offices involved in finding and assigning a test ship which had an operating schedule that would be suitable for the shipboard activities of the MPM System. In March 1981, the USS JESSE L. BROWN, FF 1089, was assigned as the test ship for the project.

4. The existing ship instruments were surveyed to determine which of those instruments could be used to obtain data for the Input Datapoints, and further, to determine which additional instruments would have to be installed to obtain the data for the remainder of the Input Datapoints. The selection of the instrumentation is covered by Section V of this report.

5. On the first ship visit, the general procedures

5. (continued)

for carrying out the MPM System were described to ship personnel and the processing of the Input Data was demonstrated by using a similar program with computer tapes that had been prepared for a performance monitoring system on a merchant ship.

6. After the initial ship visit, it was necessary to obtain additional data covering design performance and physical characteristics for machinery components. These data were provided by equipment manufacturers, shipbuilder, and Navy sources. The calculations and programming were then performed to develop the computer program that would specifically apply to the FF 1052 Class ships. At this stage of the project, the Input Datapoints and Outputs were finalized.

7. When the computer programs were completed, the procedures for processing Input Data were demonstrated and reviewed at DTNSRDC. Certain modifications were suggested, and subsequently, incorporated into the programs.

8. Some of the supplementary instrumentation had been procured prior to the assignment of the test ship and therefore, it was possible to

8. (continued)

install some instruments during a limited availability of the ship in April 1981. The remaining instruments were installed during June 1981.

9. During September 1981, DTNSRDC and contractor representatives rode the ship to provide instruction to ship personnel, to conduct tests, and to start up the MPM System. Based upon the test data, coefficients in the computer programs were adjusted to their final values and the programs were then complete.

10. Through arrangements made by DTNSRDC, the Engineering Officer of the ship sent copies of recorded datasets to DTNSRDC for review and comment. Those Datasets were studied by DTNSRDC and contractor representatives and suggestions were given to the Engineering Officer. Follow-up activity also included several visits to the ship to correct problems with instrumentation, provide additional training to newly-assigned personnel, investigate problems encountered, and to assure that the proper procedures were being followed.

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SECTION V - INSTRUMENTATION

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SECTION V INSTRUMENTATION

1. The Input Data Recording Forms as included in the appendices, show the Input Data required for performance and heat balance calculations as calculated by the computer program.

2. It was an objective of the project to use existing instrumentation as much as possible but it was found that some data essential to the program could only be obtained by installing additional instruments. To show the scope of the additional instrumentation, the Input Data Recording Forms included in the appendices to this report have been marked-up to show those items which required additional instrumentation.

3. For the supplementary Datapoints measuring temperature, thermocouples were installed. In air ducts, stack gas side of the boilers, and in low pressure piping, thermowells were installed. In high-pressure piping and on auxiliary turbine exhaust trunks, surface mounted thermocouples were installed. Thermocouple leads are fitted with quick connect/disconnect fittings so that temperature readings are obtained by using a portable, digital-

3. (continued)

readout, thermocouple indicator instrument.
For the supplementary Datapoints reading pressure, Bourdon type pressure gauges were installed in steam line locations; Bourdon type differential pressure gauges were installed to measure pressure drops across the orifices in the feed pump recirculating lines; manometers were installed for measurement of forced draft air supply pressures; and an absolute type pressure gauge was installed for measuring main condenser pressure.
RPM indicators of the vibrating reed type were installed on the boiler feed pumps.
A torque/thrust meter was installed for the measurement of shaft horsepower, propeller thrust, and propeller RPM.
For the measurement of fuel oil flow, a flowmeter of the nutating disc, positive displacement type was installed in the fuel oil service piping to each boiler.
For the measurement of the combined condensate flow from the turbogenerators, a turbine type flowmeter was installed in the turbogenerator condensate piping.
For the measurement of the drains flow from the low-pressure drains system, which includes drains

3. (continued)

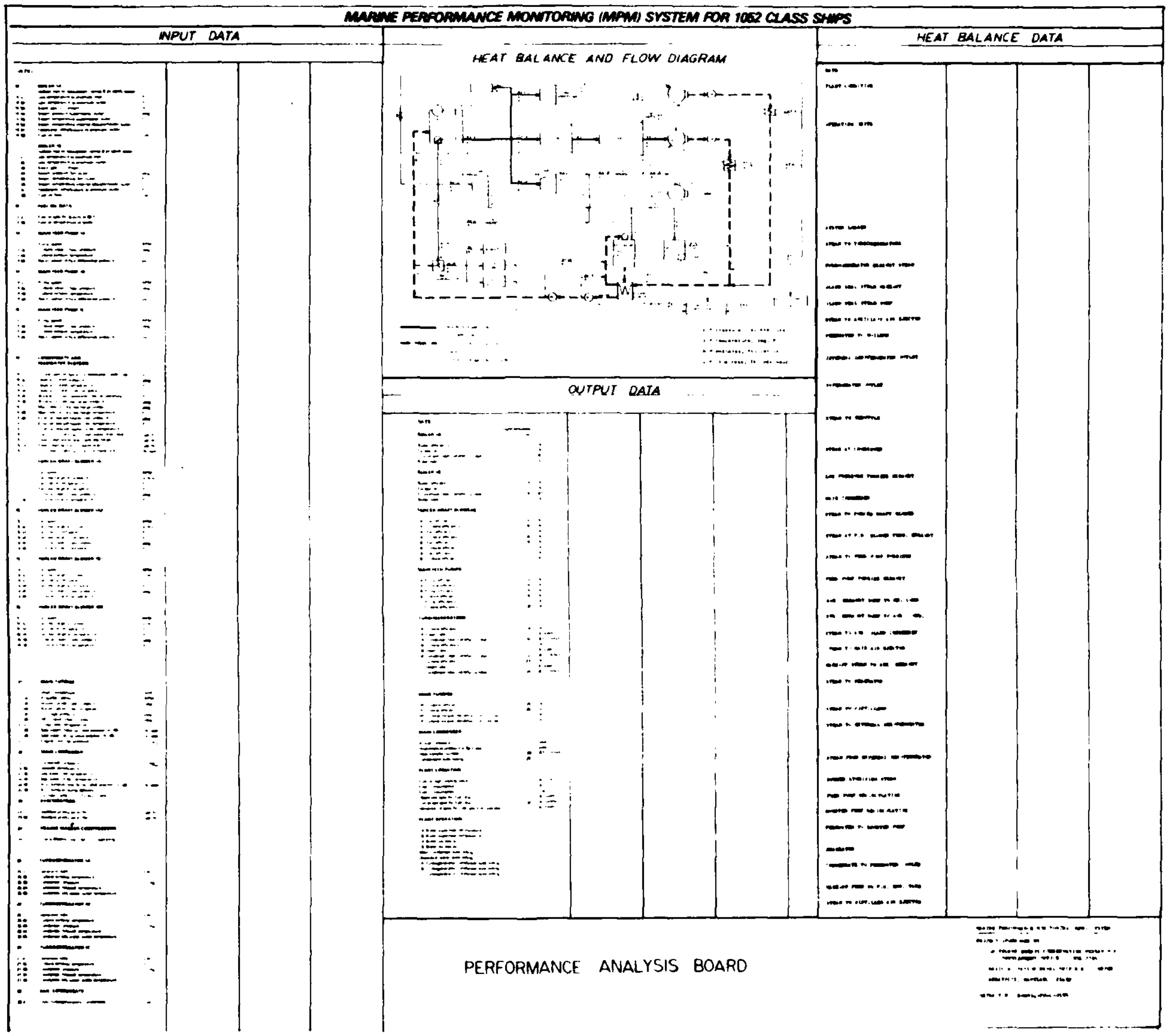
from galley and ship heating systems, to the fresh water drain tank, a nutating disc, positive displacement type flowmeter was installed.

For the measurement of the condensate flow from the fresh water drain tank to the main condensate line, a nutating disc, positive displacement type flowmeter was installed.

An oxygen analyzer was installed to provide continuous readings of the percent by volume oxygen content of the stack gases leaving the boilers. The gas sample for the analysis is taken at a point just under the economizer of each boiler. The meter readout is located in Fire Room Control.

The desktop type computer was set up in the Engineering Log Room.

Two Performance Analysis Boards were installed; one in the engineering log room and the second in the fire room. The Performance Analysis Board is used to display the input/output data and to make it convenient for comparing performance parameters of different Datasets. The arrangement of the Performance Analysis Board is shown by Fig. V-1.



ARRANGEMENT OF PERFORMANCE ANALYSIS BOARD

FIG. V-1

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SECTION VI - SYSTEM OPERATION

SECTION VI SYSTEM OPERATION

1. Training

The initial training was conducted as a briefing with NSRDC and Contractor representatives reviewing the program and demonstrating the procedure for processing data through the computer. One such session was presented to the commanding officer and the engineering officers at the very start of the program. Subsequently, similar sessions were conducted for chief petty officers and enlisted personnel. The next phase of the training was to provide instruction on the collection of data. While this is a routine similar to the one regularly used by enlisted engineering personnel in filling out the Engine Room Operating Record (NAVSEA 9230/2 (5-79), supplementary instruction was required for the flowmeters and the torque/thrust meter. During the at-sea test runs enlisted personnel collected data under the supervision of the NSRDC and Contractor representatives.

Training on the processing of data was carried out by having engineering officers and selected chief petty officers operate the computer

1. (continued)

through the cycle from the point of entering Input Data to the production of output performance data, heat balance data and trend diagrams.

After the system was in operation, the ship's engineering officer would send any questions, reports of problems, and copies of Datasets to NSRDC. NSRDC and Contractor representatives would review such reports and reply with recommendations.

2. Data collecting

A data collecting routine was established whereby two men read and record the data from the Fire Room Datapoints and one man collects the data for the Engine Room and Auxiliary Machinery Room No. 1. It was found that with any of the enlisted personnel who had a basic knowledge of the machinery space arrangement, about two hours of on-the-job type training was required to reach the level of competency needed to collect and record Input Data.

3. Data Processing

The Input Data is brought to the Engineering Log Room for processing in the computer. It

3. (continued)

was found that about eight hours of instruction was required for an engineering officer to learn the procedures for processing data. About half of that instruction time was allocated to "hands-on" operation of the computer. Due to several changes in ship personnel during the course of the project, two Engineering Officers and two assistants were involved with the start-up of the MPM System and it was found that all four officers were well-founded in the use of desktop type computers and therefore the instruction was mainly devoted to learning the specific procedures that apply to the MPM System.

Output Data printouts are displayed on the Performance Analysis Board which is mounted on a bulkhead in the Log Room. Duplicate copies of the computer printouts are displayed on a Performance Analysis Board in the Fire Room. Initial experience with the system suggested that it would be advantageous to have a second Performance Analysis Board in the Fire Room in order to provide timely performance monitoring data for the boiler operation. Input Data, Output Data, and Heat Balance Data are filed in the Input/Output File. This file is in the form of a loose-leaf notebook and is divided

3. (continued)

into sections corresponding to the established base ranges of propeller RPM. In order to organize stored data so that it is meaningful for the Data Trend analysis, individual computer cassettes are assigned to specific RPM ranges so that the data within one RPM range will not be intermingled with datasets from other RPM ranges. The assigned RPM operating ranges are as follows:

		RPM RANGE
I	1 boiler	85 to 90
II	1 boiler	115 to 120
III	1 boiler	130 to 135
IV	2 boilers	135 to 140
V	2 boilers	190 to 195

Trend Diagrams are filed in a separate notebook file. At the option of the computer operator, the key parameters of any dataset can be stored in the memory bank section of the cassette so that the data will be available for Trend Diagrams at any time in the future. The key parameters are designated by a series of identification numbers, as listed on the Output Data Form.

A separate computer program and cassette applies to the monitoring of the hull fouling condition. Hull speed, shaft horsepower, propeller revolutions per minute, and thrust are the items of Input Data. Output Data includes increment of speed lost at constant shaft horsepower, increment of additional shaft horsepower to maintain a set speed, and

3. (continued)

trend analysis to project when certain assigned limits will be encountered.

4. Performance Analysis

The computer Output includes "straight language" guidance as to whether certain critical parameters are "HIGH", "LOW", or "OK". However, the performance analysis function depends upon the operator to compare the Input/Output values of a given dataset with previous data and to evaluate the causes for variations. In particular it is necessary for an operator to accumulate experience with the MPM System so as to be able to identify how specific changes in the plant operating conditions will effect the specific fuel rates. An item by item comparison is conveniently organized on the Performance Analysis Board and such comparisons can identify specific adjustments that should be made in the "setting" of the plant. However additional gains can be made by coupling successive datasets with iterative adjustments to the plant. The performance analysis function was not fully developed during the initial operating period. The ship has been provided with a test schedule which is intended to develop the data required for selecting conditions

4. (continued)

that will optimize fuel conservation. Additionally, the test results will show comparisons of performance for certain auxiliary machinery components. For example, it is planned to compare the performance of the three main feed pumps.

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SECTION VII - OPERATIONAL EXPERIENCE

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SECTION VII OPERATIONAL EXPERIENCE

1. Instrument Problems

In order to obtain accurate readings of air pressures at the forced draft blower discharges, manometers were installed as part of the supplementary instrumentation. The initial selection of manometer was based upon using a fluid with a specific gravity of 2.95. This would have given a scale range that could be accommodated within space restrictions in the ship. During installation it was discovered that the manometer fluid had an offensive odor and was therefore unacceptable since it would create a hazard if the liquid was discharged into the Fireroom. Accordingly, the manometers were installed with water as the working fluid. This change reduced the operating range of the instrument. The scales were replaced. In service it was discovered that surges in air pressure exceeded the range of the instrument with the result that the fluid was displaced out of the instrument. Modifications to the instrument piping are being studied and alternate instruments are being considered. In the meantime, the boiler

1. (continued)

draft gauges are being used to obtain data. Failures of the flowmeter in the low pressure drain main (Datapoint 16.14) have occurred. The first failure occurred soon after initial installation and it was found that the disc had seized in the housing. Some foreign particles were found but the failure was mainly attributed to an interruption of the water flow by a momentary steam flow. A similar failure occurred after the system was in service. This item is being investigated further.

2. Program Problems

During the initial period of operation, some difficulties were experienced with the program interrupting when a particular dataset contained a contradiction between the reading for main condenser pressure and the theoretical main condenser pressure corresponding to the hotwell temperature reading. It was found that the program required a greater accuracy for these two readings than was possible from the particular instruments involved. The program was revised to include an alternate method of calculation which is activated if the contradiction does occur.

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SECTION VIII - SHIP PERSONNEL REACTIONS/ACCEPTANCE

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SECTION VIII SHIP PERSONNEL REACTIONS/ACCEPTANCE

1. Engineering Officer and Assistants

   Levels of knowledge and experience required for operating the computer to the data processing procedures of the MPM System were found to be well within the capabilities of the engineering officers, who also were philosophically supportive of the concept of a performance monitoring system. The pressures of higher priority activities have on some occasions preempted the time of the engineering officers to the extent that they have not followed through on prescribed MPM procedures. In particular, more time could have been spent in analysis of results.

2. Chief Petty Officers

   At the outset of the project, the Chiefs in varying degrees, expressed reservations on the practical aspects of making the MPM System work. Considerations of workload, additional paper work, instrument maintenance, and the need for continuous training of new personnel seemed to be the basis of the reservations. As the project went forward,

2. (continued)

the Chiefs became more involved in the activities of the project and the participation appeared to neutralize, at least to some degree, the initial reservations. While the Chiefs did not have any background experience on computers, it is noteworthy that they learned readily the particular computer routines for processing the MPM System Data. The Chiefs provided the experience and recommendations concerning practical operation of the plant and they demonstrated that they can make valuable contributions to the performance analysis activity.

3. Other Personnel

Various other personnel were involved in assisting with the installation of supplementary instruments and in collecting and recording Data. No reactions have been noted.

4. Long Term Evaluation

DTNSRDC has prepared an extensive questionaire which will be used to assemble the information that is required to evaluate the MPM System over an extended period of time.

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SECTION IX - CONCLUSIONS AND RECOMMENDATIONS

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SECTION IX CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

Since the evaluation of the MPM System has not been completed, the following conclusions are tentative and are based upon the observations and experience that have been accumulated during the period up to the date of this report.

A. The original instrumentation, as furnished when the ship was built, was not adequate to properly monitor the performance of certain machinery components and was inadequate for providing a heat balance for the overall plant.

B. The addition of an instrument for reading percent oxygen in the boiler stack gases provides the capability to make a major improvement in fuel conservation.

C. The addition of fuel oil meters provides the capability of making fuel oil consumption values, on an hourly and a daily basis, more readily available for the operating personnel. This, in turn, should promote a greater awareness of

1. (continued)

fuel conservation.

D. The MPM routine assists personnel in learning the arrangements of piping systems and components that make up the power plant. Particularly newly-assigned personnel are able to learn the piping systems more readily by referring to the name tags that are located at each of the Datapoints.

E. A performance monitoring system may be less effective on a ship with a service load pattern and operating conditions as observed to date on the test ship. Military operations require extensive operating periods where the load on the power plant is continually changing, whereas performance monitoring requires that data be collected only at steady steaming conditions.

F. Experience to date would indicate that any type of MPM system on the test ship would be continued in active use only as long as substantial supporting activities are provided by an enthusiastic shore-side agency. This is not a reflection against the ship personnel as individuals but is intended to recognize the effects of existing

F. (continued)

high levels of workloads and frequent turnover of personnel.

2. Recommendations

Since the evaluation of the MPM System has not been completed, the following recommendations are tentative and are based upon the observations and experience that have been accumulated during the period up to the date of this report.

A. The Input Data Recording Forms are arranged to a format that relates to the heat balance diagram and also groups the data according to component or system. The data collection would be simplified if those forms were arranged to follow the sequence of Datapoint locations. This change was implemented somewhat by adding designations to the forms to show the levels at which the Datapoints are located.

B. The thermocouples were installed with short leads and quick-connect/disconnect attachments to facilitate the reading of the temperatures with the portable

B. (continued)

thermocouple indicator/meter. The short leads were selected to minimize cable runs and installation costs. The arrangement has been suitable for taking readings during the test and evaluation period but the connections are vulnerable to physical damage and a more practical arrangement would be to have thermocouple leads brought to a central location. This could allow the leads to be connected to a panel which would give better protection to the wiring connections. It would also expedite the collection of data since all temperature readings could be taken from one station.

C. Investigate the possibility of installing valve position indicators in Fire Room Control on the BROWN to show the operators the positions of the auxiliary exhaust make-up steam regulating valve and the two auxiliary exhaust dump regulating valves. During in-service tests on the BROWN, there were occasions when these two controls were not coordinated. Such maladjustment could cause substantial

C. (continued)

energy losses as well as disturbing plant stability.

D. On several occasions, it was observed that the operators had difficulties in stabilizing the plant to obtain steady operating conditions. The unstable conditions are manifested by oscillations of boiler combustion controls, F. D. Blowers' operating conditions, Feed Pumps' operating conditions, Boilers' operating conditions, and auxiliary exhaust back pressure. It is recommended that a concerted investigation be conducted to determine the basic causes for the unstable conditions and that appropriate repairs and modifications be made.

E. The MPM Output Data shows substantial deviations of Main Turbine efficiencies as compared to design. For example, one Dataset shows the H.P. Turbine to have a measured efficiency of 68 percent compared to a design value of 76 percent and the L. P. Turbine to have a measured efficiency of 73 percent compared to a design value of

E. (continued)

82 percent. It is recommended that this item should be investigated at the next scheduled turbine overhaul.

F. To achieve the substantial improvements in fuel conservation that can be obtained by maintaining excess air ratios at their prescribed levels, it is essential that combustion controls and fuel oil burners must be in essentially "perfect" operating order. Controls, burner registers, burner tips, and furnace refractory should be periodically inspected and maintained by competent service specialists.

G. Navy should install instruments for measuring oxygen percent in stack gases on additional ships of the class.

H. Navy should install fuel oil meters on additional ships of the class.

I. NSRDC should present recommendations concerning adequate instrumentation for implementing performance monitoring and energy conservation to NAVSEA agencies concerned with design and construction of new ships.

J. DTNSRDC should provide the leadership, technical support, material support and training to implement a rigorous continued application of the two MPM systems that are now installed on the BROWN and the BLAKELY. In addition to fulfilling the original objectives of the projects, the program should be implemented to collect reliable in-service operating data for the range of operating conditions such that the data can be analyzed and become the basis for energy conservation operational guidelines that would be issued to other ships of the class.

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
CONTRACT NO. N00014-80-C-0188

FINAL TASK REPORT

SECTION X - APPENDICES

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
CONTRACT NO. N00014-80-C-0188

FINAL TASK REPORT

SECTION X APPENDICES

1. Input Data Recording Form - FIRE ROOM
2. Input Data Recording Form - ENGINE ROOM
3. Flowmeter Data Recording Form
4. Output Data Form
5. Steam Flow Diagram and Heat Balance Form

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR 1052 CLASS SHIPS

INPUT DATA RECORDING FORM — FIRE ROOM

Date of recording ____________________
YY . MM DD HH

Item	Description	SHIPS INSTR VALUE	COR RECTION FACTOR	COR RECTED VALUE	Unit
10	**BOILER 1A (when not in operation, write 0 at each item)**				
10.01 —	Gas temperature economizer inlet				F
10.02 —	Gas temperature economizer outlet				F
10.03 —	Stack gas O_2 content				%
10.04	Steam pressure superheater outlet				psig
10.05	Steam temperature superheater outlet				F
10.06	Steam temperature internal desuperheater outlet				F
10.07 —	Feedwater temperature economizer outlet				F
10.08 —	Fuel oil flow				Gal/hr
11	**BOILER 1B (when not in operation, write 0 at each item)**				
11.01 —	Gas temperature economizer inlet				F
11.02 —	Gas temperature economizer outlet				F
11.03 —	Stack gas O_2 content				%
11.04	Steam pressure SH outlet				psig
11.05	Steam temperature SH outlet				F
11.06	Steam temperature internal desuperheater outlet				F
11.07 —	Feedwater temperature economizer outlet				F
11.08 —	Fuel oil flow				Gal/hr
12	**FUEL OIL DATA**				
12.01	Fuel oil specific gravity at 60 F				
12.02	Fuel oil temperature at boiler				F
13	**MAIN FEED PUMP 1A**				
13.01 —	Pump speed				RPM
13.02 —	Turbine steam chest pressure				psig
13.03 —	Turbine exhaust temperature				F
13.04 —	Recirculation orifice differential pressure				psi
14	**MAIN FEED PUMP 1B**				
14.01 —	Pump speed				RPM
14.02 —	Turbine steam chest pressure				psig
14.03 —	Turbine exhaust temperature				F
14.04 —	Recirculation orifice differential pressure				psi
15	**MAIN FEED PUMP 1C**				
15.01 —	Pump speed				RPM
15.02 —	Turbine steam chest pressure				psig
15.03 —	Turbine exhaust temperature				F
15.04 —	Recirculation orifice differential pressure				psi

— ADDITIONAL INSTRUMENT

INPUT DATA RECORDING FORM FIRE ROOM/FORCED DRAFT BLOWER ROOMS

No.	Item	SHIPS INSTR VALUE	CORRECTION FACTOR	CORRECTED VALUE	Unit
16	**CONDENSATE AND FEEDWATER SYSTEMS**				
16.01 —	Condensate temperature feedwater cooler inlet				F
16.02	Deaerator shell pressure				psig
16.03	Deaerator water temperature				F
16.04 —	Deaerator steam inlet temperature				F
16.05 —	Booster pumps feedwater inlet temperature				F
16.06	Booster pumps discharge pressure				psig
16.07	Main feed pumps discharge pressure				psig
16.08 —	Main feed pumps discharge temperature				F
16.09	External desuperheater inlet pressure				psig
16.10 —	External desuperheater inlet temperature				F
16.11	External desuperheater outlet temperature				F
16.12	Feedwater make up to fresh water drain tank				Gal/hr
16.13 —	Flow, fresh water drain tank discharge				Gal/hr
16.14 —	Flow, heating and hot water drain				Gal/hr
16.15	Live steam make up to aux. exhaust line				% open
17	**FORCED DRAFT BLOWER 1A1**				
17.01	Fan speed				RPM
17.02 —	Fan discharge air pressure				in H_2O
17.03 —	Fan inlet air temperature				F
17.04 —	Fan discharge air temperature				F
17.05 —	Turbine steam chest pressure				psig
17.06 —	Turbine exhaust temperature				F
18	**FORCED DRAFT BLOWER 1A2**				
18.01	Fan speed				RPM
18.02 —	Fan discharge air pressure				in H_2O
18.03 —	Fan inlet air temperature				F
18.04 —	Fan discharge air temperature				F
18.05 —	Turbine steam chest pressure				psig
18.06 —	Turbine exhaust temperature				F
19	**FORCED DRAFT BLOWER 1B1**				
19.01	Fan speed				RPM
19.02 —	Fan discharge air pressure				in H_2O
19.03 —	Fan inlet air temperature				F
19.04 —	Fan discharge air temperature				F
19.05 —	Turbine steam chest pressure				psig
19.06 —	Turbine exhaust temperature				F
20	**FORCED DRAFT BLOWER 1B2**				
20.01	Fan speed				RPM
20.02 —	Fan discharge air pressure				in H_2O
20.03 —	Fan inlet air temperature				F
20.04 —	Fan discharge air temperature				F
20.05 —	Turbine steam chest pressure				psig
20.06 —	Turbine exhaust temperature				F

INPUT DATA RECORDING FORM — *ENGINE ROOM*

Date of recording ______________
YY . MM DD HH

		SHIPS INSTR VALUE	COR RECTION FACTOR	COR RECTED VALUE	Unit
21	**MAIN TURBINE**				
21.01 —	Shaft horsepower				SHP
21.02 —	Propeller speed				RPM
21.03	Nozzle valves chest pressure				psig
21.04	Nozzle valves chest temperature				F
21.05	1st stage pressure				psig
21.06	HP exhaust steam pressure				psig
21.07	Cross over temperature				F
21.08	Seal steam make up valve position (0-100)				% open
21.09	Seal steam dump valve position (0-100)				% open
21.10	Engine room air pressure				in Hg_{abs}
22	**MAIN CONDENSER**				
22.01 —	Condenser pressure				in Hg_{abs}
22.02	Hotwell temperature				F
22.03	Sea water inlet temperature				F
22.04	Sea water outlet temperature				F
22.05	Aux. exhaust line dump valve position (0-100)				% open
22.06	Aux. exhaust dump delivery: (to main cond. = 1, To aux. cond. = 0)				
23	**EVAPORATORS**				
23.01	Distillate produced by No. 1				Gal/hr
23.02	Distillate produced by No. 2				Gal/hr
24	**PRAIRIE MASKER COMPRESSORS**				
24.01	Prairie Masker: Secured = 1, operating = 0				

— ADDITIONAL INSTRUMENT

		SHIPS INSTR VALUE	COR RECTION FACTOR	COR RECTED VALUE	
25	**TURBOGENERATOR 1A**				
25.01	Generator load				kW
25.02	Turbine exhaust temperature				F
25.03	Condenser pressure				in Hg_{Vac}
25.04	Condenser hotwell temperature				F
25.05	Condenser sea water outlet temperature				F
26	**TURBOGENERATOR 1B**				
26.01	Generator load				kW
26.02	Turbine exhaust temperature				F
26.03	Condenser pressure				in Hg_{Vac}
26.04	Condenser hotwell temperature				F
26.05	Condenser sea water outlet temperature				F
27	**TURBOGENERATOR 1C**				
27.01	Generator load				kW
27.02	Turbine exhaust temperature				F
27.03	Condenser pressure				in Hg_{Vac}
27.04	Condenser hotwell temperature				F
27.05	Condenser sea water outlet temperature				F
28	**AUX. CONDENSATE**				
28.01 —	Flow turbogenerators condensate				Gal/hr

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
FLOWMETER DATA RECORDING FORM

FIRE ROOM

Date of recording ____ YY MM DD HH

	Meter	Time
10.08 Fuel Oil Flow, Boiler 1A		
Second Meter Reading	______	______
First Meter Reading	______	______
Meter Reading Difference	______	
Time Difference, minutes		______

Fuel Oil Flow = $\frac{\text{meter rdg. diff. x 60}}{\text{time diff}}$ = ______ GPH

	Meter	Time
11.08 Fuel Oil Flow, Boiler 1B		
Second Meter Reading	______	______
First Meter Reading	______	______
Meter Reading Difference	______	
Time Difference, minutes		______

Fuel Oil Flow = $\frac{\text{meter rdg. diff. x 60}}{\text{time diff.}}$ = ______ GPH

	Meter	Time
16.13 Flow, FWDT Discharge		
Second Meter Reading	______	______
First Meter Reading	______	______
Meter Reading Difference	______	
Time Difference, Minutes		______

Flow, FWDT Discharge = $\frac{\text{meter rdg. diff. x 60}}{\text{time diff.}}$ = ______ GPH

	Meter	Time
16.14 Flow, heating & HW Drains		
Second Meter Reading	______	______
First Meter Reading	______	______
Meter Reading Difference	______	
Time Difference, minutes		______

Flow, Htg. and HW Drains = $\frac{\text{meter rdg. diff. x 60}}{\text{time diff.}}$ = ______ GPH

APPENDIX 3

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR FF 1052 CLASS SHIPS
FLOWMETER DATA RECORDING FORM

ENGINE ROOM

Date of Recording: YY MM DD HH

23.01 Distillate produced by No. 1 Distiller

	METER	TIME
Second Meter Reading	________	________
First Meter Reading	________	________
Meter Reading Difference	________	
Time difference, minutes		________

$$\text{Distillate Flow Rate} = \frac{\text{meter rdg. difference x 60}}{\text{time difference}} = \text{GPH}$$

23.02 Distillate produced by No. 2 Distiller

	METER	TIME
Second Meter Reading	________	________
First Meter Reading	________	________
Meter Reading Difference	________	
Time Difference, minutes		________

$$\text{Distillate Flow Rate} = \frac{\text{meter rdg. diff. x 60}}{\text{time difference}} = \text{GPH}$$

AUXILIARY MACHINERY ROOM NO. 1

28.01 Flow, turbogenerator condensate

	METER	TIME
Second Meter Reading	________	________
First Meter Reading	________	________
Meter Reading Difference	________	
Time Difference, minutes		________

$$\text{Condensate Flow Rate} = \frac{\text{meter rdg. diff. x 60}}{\text{time difference}} = \text{GPH}$$

MARINE PERFORMANCE MONITORING (MPM) SYSTEM FOR 1052 CLASS SHIPS

OUTPUT DATA FORM

BOILER 1A	*Trend parameter no:*		
Boiler efficiency	(1)		%
Excess air			%
Economizer heat transfer number	(2)		BTU/ft²hrF
Boiler load			%

BOILER 1B			
Boiler efficiency	(3)		%
Excess air			%
Economizer heat transfer number	(4)		BTU/ft²hrF
Boiler load			%

FORCED DRAFT BLOWERS			
1A1 Fan efficiency	(5)		%
1A1 Turbine efficiency	(6)		%
1A2 Fan efficiency	(7)		%
1A2 Turbine efficiency	(8)		%
1B1 Fan efficiency	(9)		%
1B1 Turbine efficiency	(10)		%
1B2 Fan efficiency	(11)		%
1B2 Turbine efficiency	(12)		%

MAIN FEED PUMPS			
1A Pump efficiency	(13)		%
1A Turbine efficiency	(14)		%
1B Pump efficiency	(15)		%
1B Turbine efficiency	(16)		%
1C Pump efficiency	(17)		%
1C Turbine efficiency	(18)		%

TURBOGENERATORS			
1A Turbine efficiency	(19)		%
1A Steam rate			lb/kWhr
1A Condenser heat transfer number	(20)		BTU/ft²hrF
1B Turbine efficiency	(21)		%
1B Steam rate			lb/kWhr
1B Condenser heat transfer number	(22)		BTU/ft²hrF
1C Turbine efficiency	(23)		%
1C Steam rate			lb/kWhr
1C Condenser heat transfer number	(24)		BTU/ft²hrF

APPENDIX 4

MAIN TURBINE

HP Turbine efficiency	(25)		%
LP Turbine efficiency	(26)		%
HP Turbine torque, deviation from normal			%
LP Turbine torque, deviation from normal			%

MAIN CONDENSER

Actual pressure			psia
Hypothetical pressure at 60 F sea	(27)		psia
Heat transfer number	(28)		BTU/ft²hrF
Condensate subcooling	(29)		F

PLANT CONDITION

Fuel oil high heating value			BTU/lb
Fuel consumption			lb/hr
Fuel consumption			Gal/hr
Observed specific fuel rate			lb/SHPhr
Corrected specific fuel rate	(30)		lb/SHPhr
Deviation of specific fuel rate from standard			lb/SHPhr

PLANT OPERATION

1A Boiler superheat temperature			
1B Boiler superheat temperature			
1A Boiler excess air			
1B Boiler excess air			
Main condenser subcooling			
Deaerator water subcooling			
1A Turbogenerator condenser subcooling			
1B Turbogenerator condenser subcooling			
1C Turbogenerator condenser subcooling			

Comments:

____

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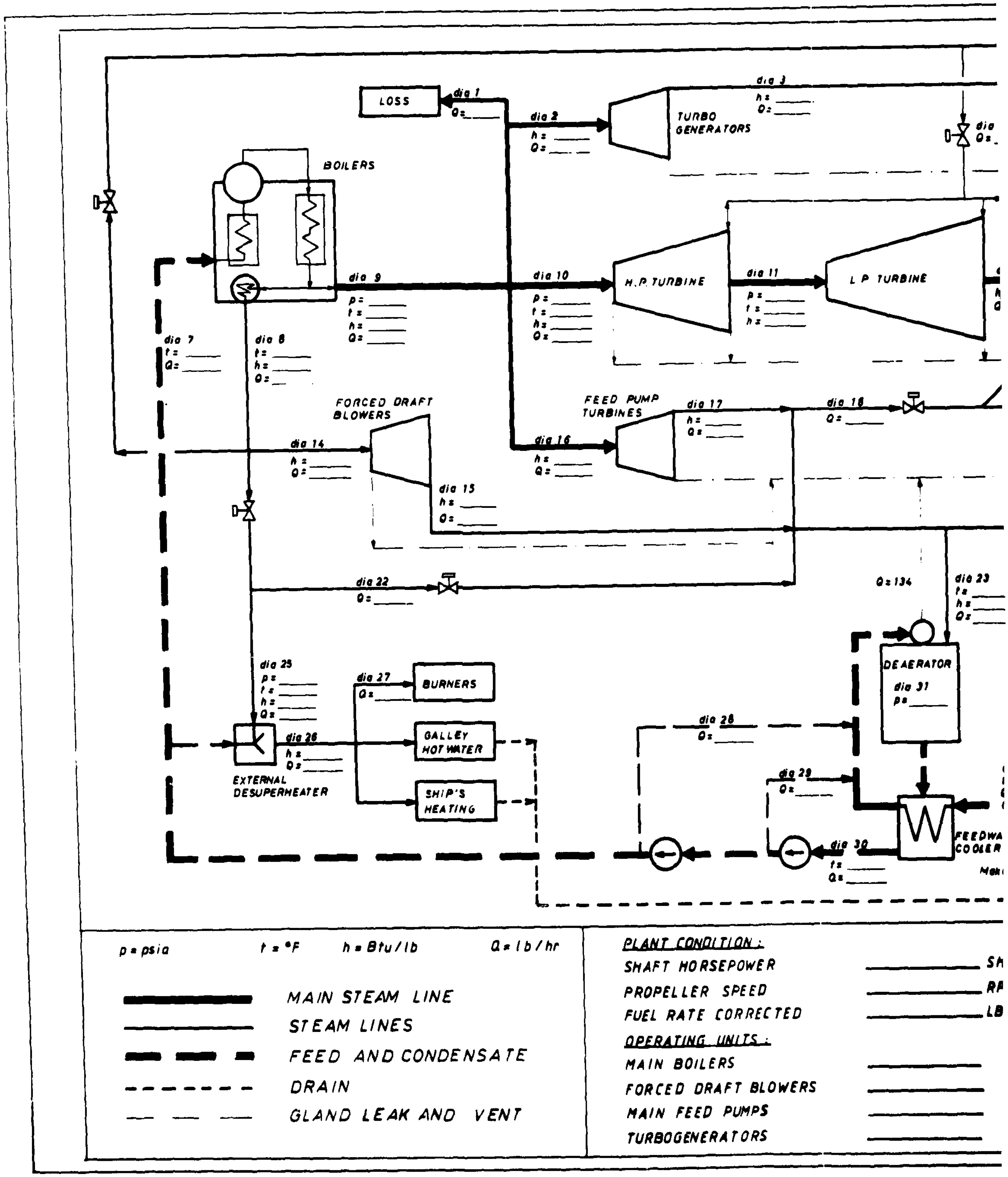
____

____

Signature



LOSS
dia 1
Q=
dia 2
h=
Q=
dia 3
h=
Q=
TURBO GENERATORS
BOILERS
dia 9
p=
t=
h=
Q=
dia 10
p=
t=
h=
Q=
H.P. TURBINE
dia 11
p=
t=
h=
L.P. TURBINE
dia 7
t=
Q=
dia 8
t=
h=
Q=
FORCED DRAFT BLOWERS
FEED PUMP TURBINES
dia 17
h=
Q=
dia 18
Q=
dia 14
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Q=
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Q=134
dia 23
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h=
Q=
DEAERATOR
dia 31
p=
dia 25
p=
t=
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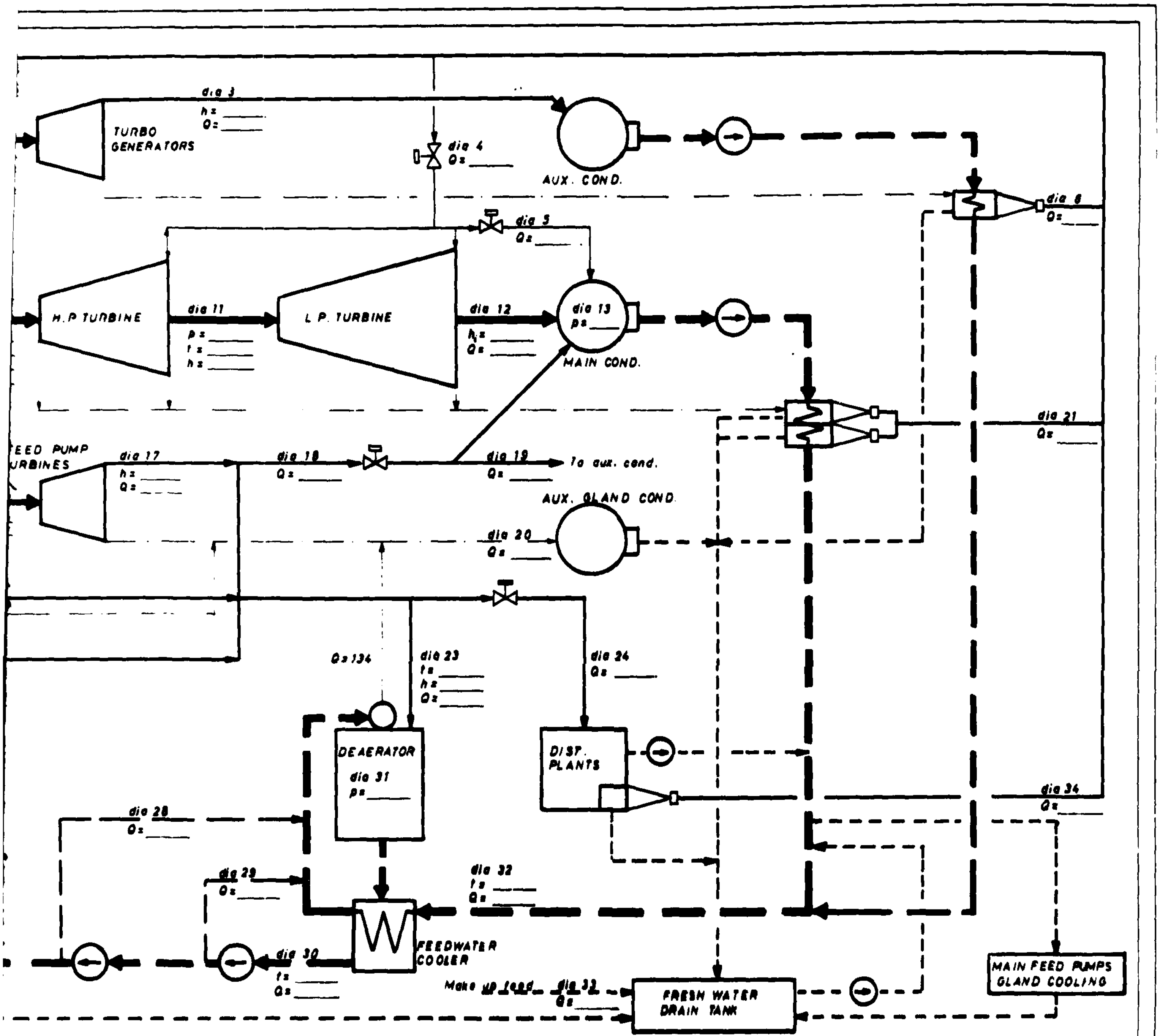
Q=
dia 27
Q=
BURNERS
dia 26
h=
Q=
GALLEY HOT WATER
SHIP'S HEATING
EXTERNAL DESUPERHEATER
dia 28
Q=
dia 29
Q=
dia 30
t=
Q=
FEEDWA COOLER
p = psia
t = °F
h = Btu/lb
Q = lb/hr
MAIN STEAM LINE
STEAM LINES
FEED AND CONDENSATE
DRAIN
GLAND LEAK AND VENT
PLANT CONDITION:
SHAFT HORSEPOWER
PROPELLER SPEED
FUEL RATE CORRECTED
OPERATING UNITS:
MAIN BOILERS
FORCED DRAFT BLOWERS
MAIN FEED PUMPS
TURBOGENERATORS



PLANT CONDITION:

SHAFT HORSEPOWER ____________ SHP

PROPELLER SPEED ____________ RPM

FUEL RATE CORRECTED ____________ LB/SHP HR

OPERATING UNITS:

MAIN BOILERS ____________

FORCED DRAFT BLOWERS ____________

MAIN FEED PUMPS ____________

TURBOGENERATORS ____________

STEAM FLOW DIAGRAM & HEAT BALANCE

MARINE PERFORMANCE MONITORING SYSTEM (MPM)
FOR 1052 CLASS SHIPS

DATE OF RECORDING:

MPM SYSTEM

APPENDIX 5 2

END

DATE

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